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Impact of global warming on the design and performance of air-conditioned office buildings in Australia

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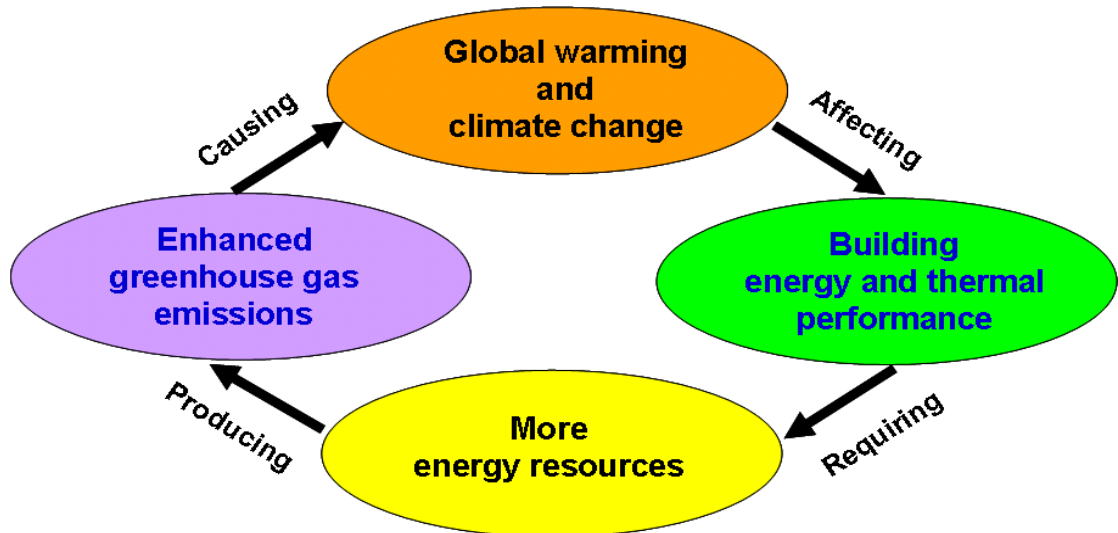
Overview of Presentation

- Research background
- **Research methodology**
- Results and discussions
- **Conclusion**



Research Background

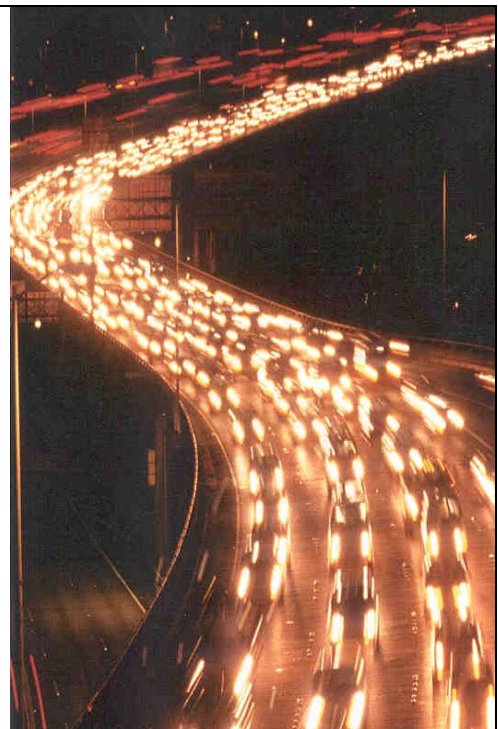
Why this research



Research Background



According to Australian Greenhouse Office, buildings contribute **more** greenhouse gases than all the cars on Australian roads !!



Research Background

Impact of climate change on built environment

- Building energy uses;
- Internal thermal environment;
- External fabric;
- Structural integrity;
- Construction process;
- Service infrastructure.

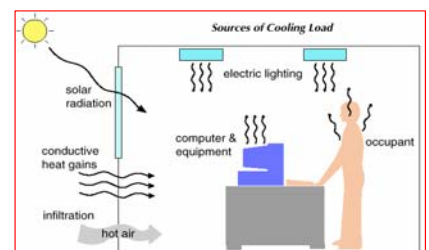


Research Background

Why Building simulation

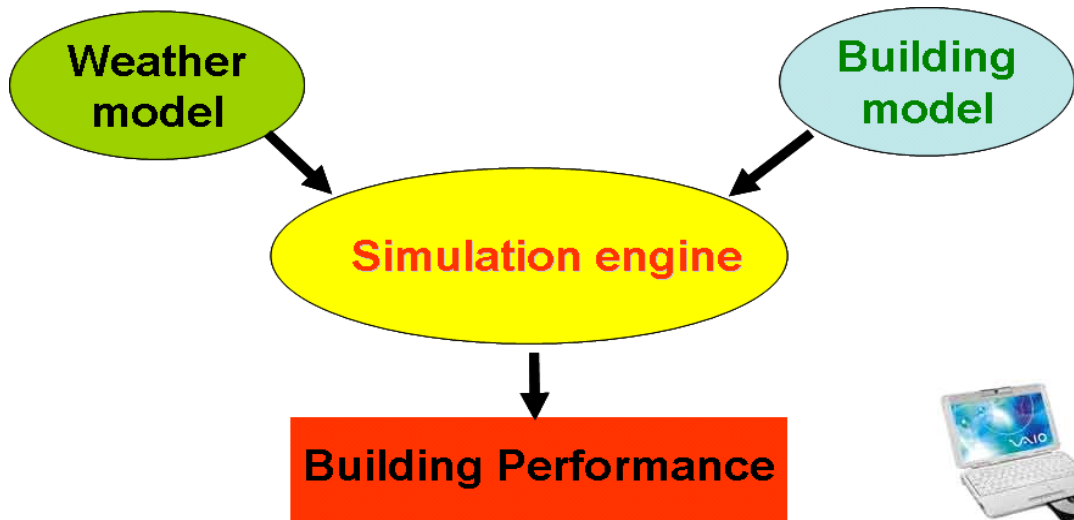


- The interaction between the building systems and global warming is extremely complex, being of **dynamic** nature and involving a large number of variables.
- In many cases the use of building simulation techniques can be the **only** realistic approach.



Methodology

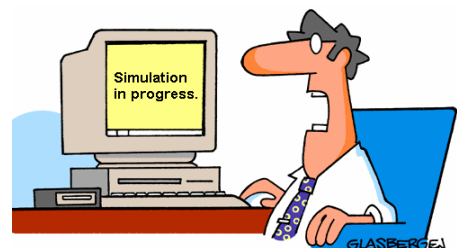
Building simulation method



Methodology: Simulation engine

Building simulation engine DOE-2.1E

- Developed by world-leading organizations
- Have passed through extensive verification process
- Fully dynamic
- Source codes open for inspection

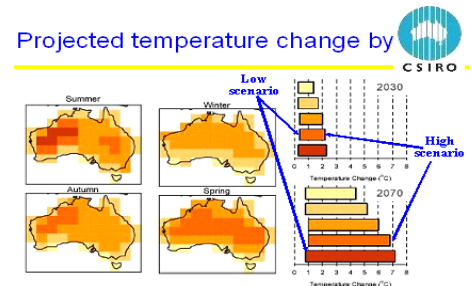


Methodology: weather

Weather scenarios

There will be five weather scenarios used for this research:

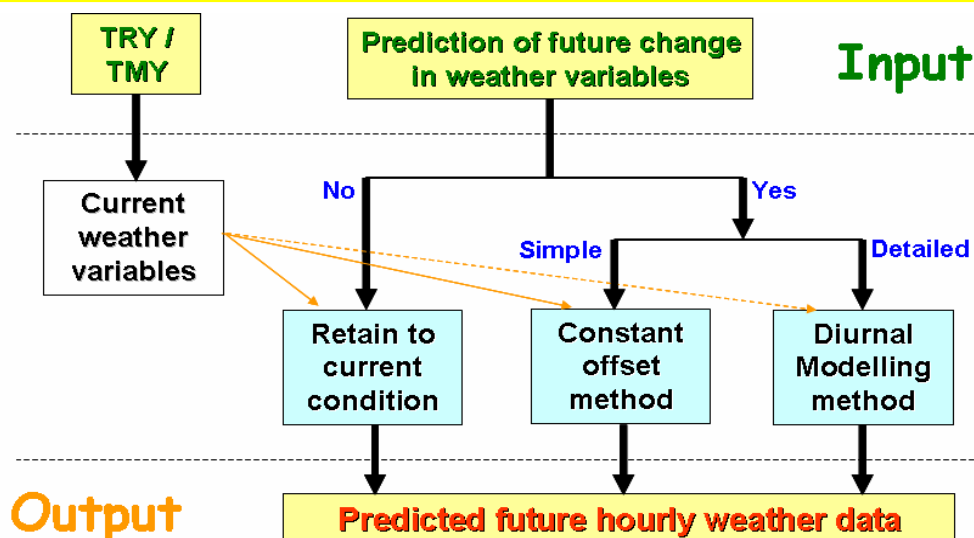
- Current weather scenario;
- Future weather scenarios
 1. 2030 Low scenario
 2. 2030 High scenario
 3. 2070 Low scenario
 4. 2070 High scenario



Methodology: weather data

Method for future weather data generation

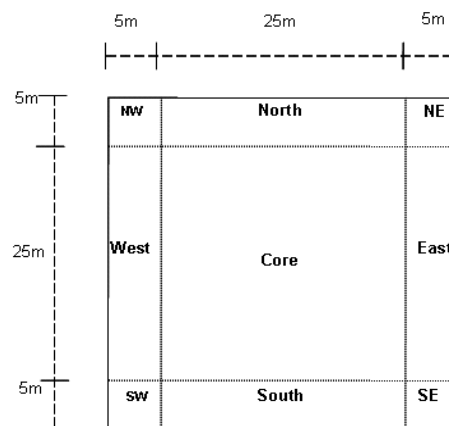
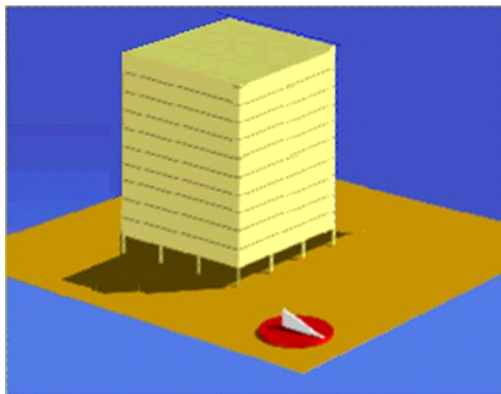
Global climate model is used to project seasonal temperature increase, which is then forced on current weather variables



Methodology: building model

The sample building model

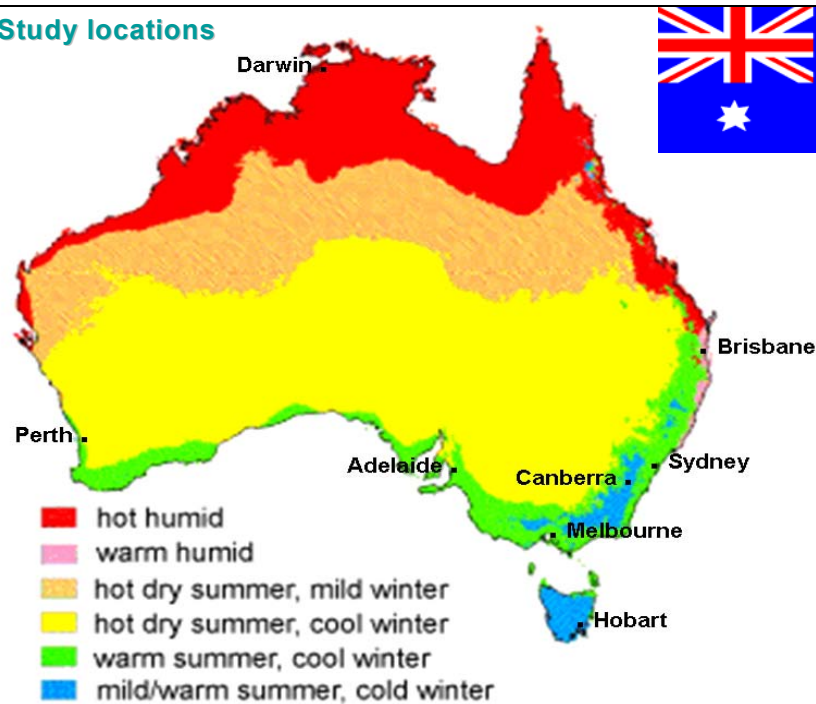
The building is only designed to cope with current weather data



Australian Building Codes Board



Methodology: Study locations



Methodology

Building performance indicators



There are **two** indicators used to measure indoor thermal environment and building energy performance respectively:

- One is the percentage of occupied hours (8am to 5pm) in temperature exceeding 25°C. This will be used to measure the **overheating** problem;
- Another is the change of building cooling load and total energy use. This will be used to illustrate the impact of global warming on the building **energy** performance.

Methodology: CO₂ estimation

Estimation of the change in CO₂ emission

The annual greenhouse gas emission (GHG)
=
Emission Factor × Energy Intensity × Floor Area

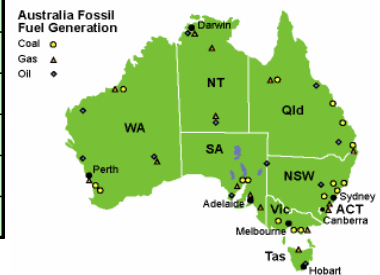
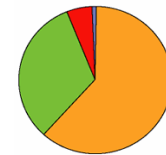
- **GHG** - kg CO₂ equivalent/yr;
- **Emission Factor** - kg CO₂ equivalent/kWh;
- **Energy Intensity** - kWh/m²yr;
- **Floor Area** - m².



Methodology: CO₂ estimation

Emission factors for electricity generation in Australia

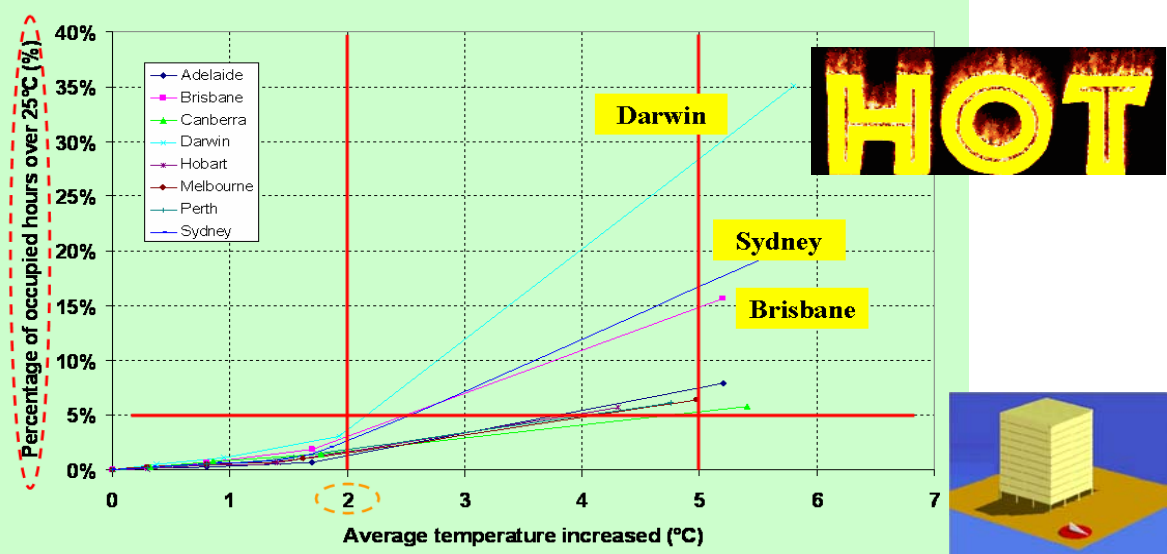
State	Full Fuel Cycle Emission Factor	
	(kg CO ₂ equivalent/kWh)	(kg CO ₂ equivalent/GJ)
New South Wales	1.054	293
Australian Capital Territory	1.054	293
Victoria	1.392	387
Queensland	1.058	294
South Australia	0.96	267
West Australia	1.053	293
Tasmania	0.006	2
Northern Territory	0.742	206



Results and Discussion

Indoor thermal environment

(% of indoor temperature > 25°C)

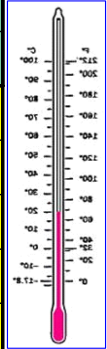


Results and Discussion

Indoor thermal environment

(% of indoor temperature > 25°C)

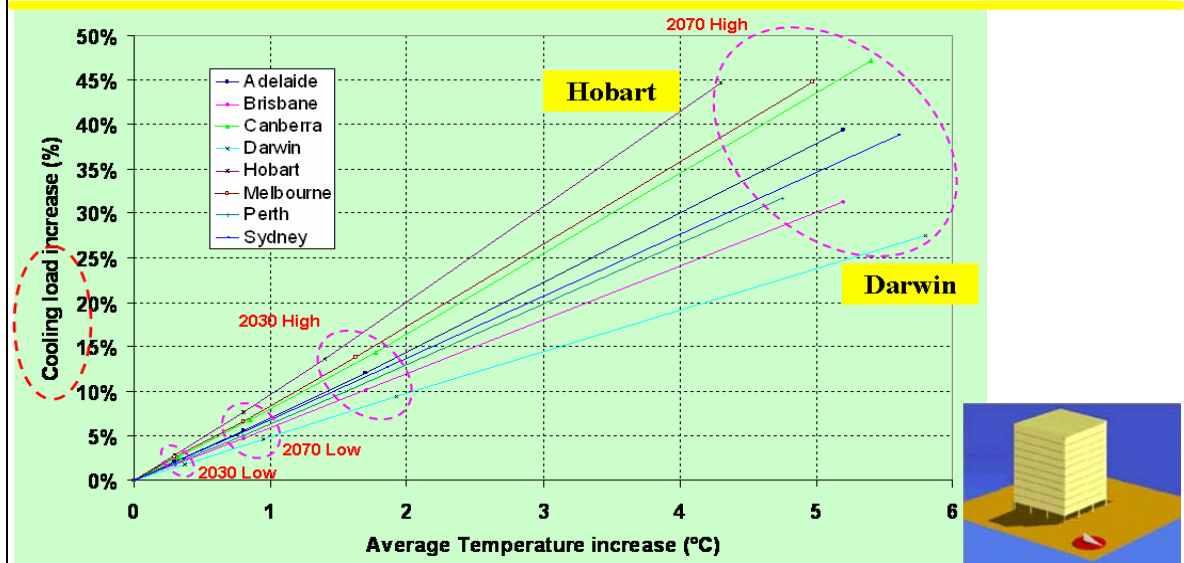
Location	Current	2030		2070	
		Low	High	Low	High
Adelaide	0.0%	0.1%	0.7%	0.2%	8.0%
Brisbane	0.0%	0.1%	1.9%	0.7%	15.7%
Canberra	0.0%	0.2%	1.4%	0.8%	5.8%
Darwin	0.0%	0.5%	3.1%	1.1%	35.0%
Hobart	0.0%	0.1%	0.7%	0.4%	5.7%
Melbourne	0.0%	0.2%	1.0%	0.5%	6.4%
Perth	0.0%	0.2%	1.2%	0.5%	6.1%
Sydney	0.0%	0.2%	2.0%	0.7%	19.6%



Results and Discussion

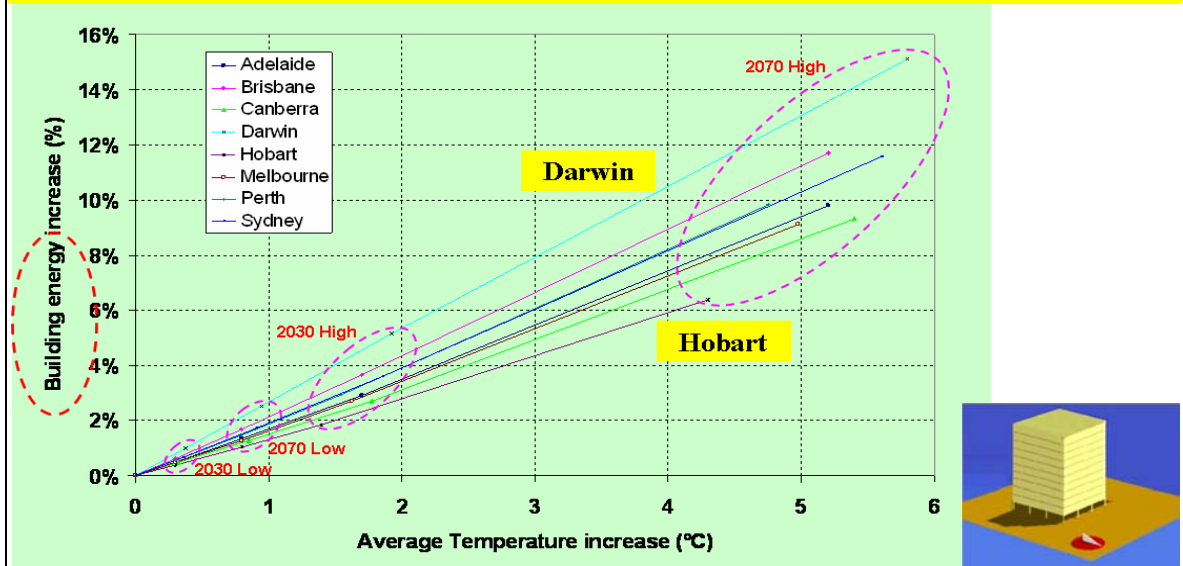
Building energy performance

(cooling load)



Results and Discussion

Building energy performance (total energy use)



Results and Discussion

Projected annual increase of CO₂ emission (kg CO₂ equivalent/m²)



Location	Year of 2030		Year of 2070	
	Low	High	Low	High
Adelaide	1.1	6.5	3.0	21.8
Brisbane	1.7	9.9	4.6	31.7
Canberra	1.1	6.3	2.9	21.8
Darwin	2.3	11.8	5.8	34.6
Hobart	0.0	0.0	0.0	0.1
Melbourne	1.5	8.3	3.9	28.3
Perth	1.4	7.5	3.8	25.2
Sydney	1.6	9.0	4.3	29.1

Results and Discussion

Projected annual increase of CO₂ emission

(kg CO₂ equivalent for modelled office building)



Location	Year of 2030		Year of 2070	
	Low	High	Low	High
Adelaide	13385	79333	36248	267099
Brisbane	20935	121429	55921	388913
Canberra	13627	77272	35857	267166
Darwin	27841	144138	70819	423551
Hobart	57	280	154	971
Melbourne	18422	101993	47540	346935
Perth	17028	92324	45959	309180
Sydney	20134	110507	52694	357009

Results and Discussion

New building designed under future projected climate

(Cooling capacity)

City	Current condition		2070 High scenario condition		Required capacity increase	
	(kW)	(W/m ²)	(kW)	(W/m ²)	(W/m ²)	%
Adelaide	1581	129	2150	176	46	36%
Brisbane	1719	140	2319	189	49	35%
Canberra	1527	125	2132	174	49	40%
Darwin	2143	175	3109	254	79	45%
Hobart	1151	94	1486	121	27	29%
Melbourne	1577	129	2020	165	36	28%
Perth	1752	143	2303	188	45	31%
Sydney	1601	131	2554	208	78	59%

Results and Discussion

New building designed under future projected climate

(Cooling load at weather condition of 2070 high scenario)

Location	Design at Current Climate			Design at Future Climate		Difference
	Current	2070 High		2070 High		
	Cooling load (MWH)	Cooling load (MWH)	Increase	Cooling load (MWH)	Increases	
Adelaide	2026	2824	39.3%	2956	45.9%	6.5%
Brisbane	2943	3863	31.3%	4019	36.6%	5.3%
Canberra	1678	2469	47.2%	2565	52.9%	5.7%
Darwin	4395	5605	27.5%	6061	37.9%	10.4%
Hobart	1280	1851	44.7%	1928	50.6%	6.0%
Melbourne	1722	2492	44.7%	2574	49.5%	4.7%
Perth	2487	3275	31.7%	3390	36.3%	4.6%
Sydney	2408	3342	38.8%	3513	45.9%	7.1%

Conclusion

Conclusion (1)



- Global warming will entail new conditions for the built environment.
- The thermal behavior of existing air conditioned office buildings, which are typically designed based on current weather data, may also be changed.
- This paper has evaluated the impact of global warming on the design and performance of air-conditioned office buildings in Australia, which includes:
 - The likely increase of cooling loads imposed by potential global warming
 - The probable indoor temperature increases due to possible undersized air-conditioning system
 - The possible change in energy use and CO₂ emission of Australian office buildings.

Conclusion

Conclusion (2)



Through the building simulation technique, it has been found

- The existing office buildings would generally be able to adapt to the increasing warmth of 2030 year Low and High scenarios projections and 2070 year Low scenario projection.
- For the 2070 year High scenario, the study indicates that the existing office buildings, in all capital cities except for Hobart, will suffer from overheating problems.
- When the annual average temperature increase exceeds 2°C “threshold”, the risk of current office buildings subjected to overheating will be significantly increased.
- With an increase of external air temperature more than 5°C, all the office buildings regardless where they are located would suffer from the overheating problem.

Conclusion

Conclusion (3)



For existing buildings which are designed under current climate condition, it has been shown that

- There is a nearly linear correlation between the increase of average external air temperature and the increase of building cooling load and total energy use.
- The increases of cooling load for existing buildings vary significantly (from 2% to 47%), depending on the assumed future climate scenarios, as well as different locations.

For the new buildings, in which the possible global warming has been taken into account in the design,

- A further increase of 4-10% of building cooling load would be required for the 2070 High scenario to improve the building thermal comfort to an acceptable standard.
- The (corresponding) required increases of the cooling capacities for the new buildings in comparison with the existing buildings vary from 27 W/m² (Hobart) to 79 W/m² (Darwin).

Conclusion



Conclusion (4)

If the energy source is assumed to be the electricity, it is found that

- Due to different fuel types and/or methods used to generate electricity, emission factors used to estimate CO₂ emission vary significantly between different states.
- in comparison with current weather scenario, the increased energy uses would translate into the increase of CO₂ emissions by 0 to 34.6 kg CO₂ equivalent/m², varying with different future weather scenarios and with different locations.

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